National Aeronautics and Space Administration

Novel Exercise Hardware Requirements, Development, and Selection Process for Long-Duration Spaceflight

A.S. Weaver,[1] J.H. Funk,[2] N.W. Funk,[2] J.K. De Witt,[3] R.S. Fincke,[3] N.J. Newby,[3] E.E. Caldwell,[3] C.C. Sheehan,[2] C. Moore,[4] L. Ploutz-Snyder,[5] L.H. Loerch,[4] and G.P. Perusek[1]

[1]NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135 | [2]ZIN Technologies, 6745 Engle Road, Middleburg Heights, OH 44130 | [3]Wyle Science, Technology & Engineering Group, 1290 Hercules Drive, Houston, TX 77058
[4]NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058 | [5]Universities Space Research Association, 3600 Bay Area Boulevard, Houston, TX 77058

Background

As NASA aims toward space travel beyond low Earth orbit (LEO) the constraints placed upon exercise equipment onboard space vehicles increase. Proposed vehicle architectures, for transit to and from locations beyond LEO, call for limits to equipment volume, mass, and power consumption that are more stringent than device requirements for the International Space Station (ISS). While NASA has made great strides in providing for the physical welfare of the crew, the equipment currently used onboard the ISS will not conform to the expected mass, volume, and power constraints of long-duration transit vehicles. The goal of the Advanced Exercise Concepts (AEC) project is to maintain the resistive and aerobic capabilities of the current ISS suite of exercise equipment, while making reductions in size, mass, and power consumption to make the equipment suitable for travel beyond LEO and future long-duration missions.

Generalized AEC Development Timeline

Requirements Development

The goal of the device development is to demonstrate, onboard the ISS, the ability of a compact device to provide an acceptable resistive load during a long-duration mission. The functional requirements were developed with a Mars transit mission as the targeted device application. Some of the high-level requirements for the device include:

- Mass: ≤100 lbm
- Stowed volume: ≤2.0 ft^3
- External power: ≤90 W
- Repair schedule: 3-year service life
- Resistive load: Provide 20 to 600 lbf
- Load ratio: Provide eccentric-to-concentric load ratio of at least 1.0:1.0

Human-in-the-Loop Testing

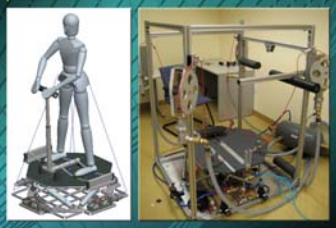
- All devices had to undergo some level of human testing to be considered for evaluation.
- Typical human evaluations collected subjective data from the user (feel, comfort, pain, etc.) to compliment objective engineering measures.
- For devices evaluated in-house by NASA, the standard resistive test protocol is shown in the table to the right. A typical set consists of a minimum of three repetitions.

Resistance Testing	Sets
Squat	3 (1 light, 1 medium, 1 heavy)
Deadlift	3 (1 light, 1 medium, 1 heavy)
Heel Raise	3 (1 light, 1 medium, 1 heavy)
Bench press	3 (1 light, 1 medium, 1 heavy)
Shoulder press	3 (1 light, 1 medium, 1 heavy)
Upright row	3 (1 light, 1 medium, 1 heavy)
Biceps curl	3 (1 light, 1 medium, 1 heavy)
Bent-over row	3 (1 light, 1 medium, 1 heavy)
Triceps press	3 (1 light, 1 medium, 1 heavy)
Diagonal deadlift	3 (1 light, 1 medium, 1 heavy)
Full-body press	3 (1 light, 1 medium, 1 heavy)

Device Evaluations

Seven devices were evaluated in August 2013 against the functional requirements.

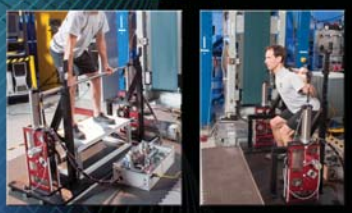
Combined Countermeasure Device (CCD)
The CCD combines balance and coordination training with resistance exercises through the use of a Stewart platform.



Controlled Resistance Exercise Device (CRED)
The CRED is a servomotor-based system that simulates inertia and provides a user-selectable eccentric overload.

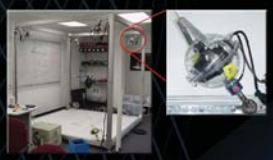
Gas Spring
The Gas Spring was designed for use in small vehicles and requires no external power to provide up to 450 lb of resistance.

High Eccentric Resistive Overload Device (HERO)
The HERO device consists of two air springs and assist motors and can provide 600 lb of resistive load and an adjustable eccentric overload.



Multimode Exercise Device (M–MED)
The M–MED provides both endurance and resistance training through the use of a flywheel and an eddy current brake.

Multipurpose, Multiaxial Isokinetic Dynamometer (M–MID)
The M–MID provides up to eight motors allowing for either free motions by the subject or prescribed motions programmed into the software.



Wyle Flywheel
The Wyle flywheel uses two different pulley systems to provide both aerobic and resistive modes in a system requiring no external power.

Downselect

- Based on the known information from these devices, the AEC team scored each device against the functional requirements.
- The iExercise panel, consisting of subject matter experts from various NASA organizations, selected the HERO and the M–MED from the seven listed above for further evaluation.
- Two new devices are currently ready for human-in-the-loop testing. A final device decision will be made during 2014 after these devices have been tested.

www.nasa.gov